HIGH-P_T SUPPRESSION IN HEAVY ION COLLISIONS FROM THE BRAHMS EXPERIMENT AT RHIC

SELEMON BEKELE FOR THE BRAHMS COLLABORATION

The University of Kansas,
1082 Mallot Hall, 1251 Wescoe Hall Drive,
Lawrence, KS 66045, USA
E-mail: bekeleku@ku.edu

In central nucleus-nucleus collisions, deviations from binary scaling at high-p_T reveal themselves as a suppression in the transverse momentum distribution of produced particles as measured by R_{cp}, the ratio of central to peripheral data scaled by the number of binary collisions. The system size dependence of R_{cp} may help disentangle the interplay of initial (e.g. gluon saturation) and final (e.g. parton energy loss) state effects which are thought to modify the scaling behavior of the high-p_T suppression. Here we present results on R_{cp} of charged hadrons from the BRAHMS experiment comparing results from AuAu, CuCu and dAu collisions.

1. Introduction

The study of high-p_T hadron production may provide an insight into the properties of the highly excited partonic matter, often called the Quark Gluon Plasma (QGP), created in high energy heavy ion collisions. Recent data from RHIC reveal that the mid-rapidity hadron spectra at high-p_T in central AuAu collisions are strongly suppressed relative to scaled pp spectra[1].

Measurements of the nuclear modification factor are consistent with partonic energy loss in the larger interaction volume corresponding to central collisions suggesting that high-p_T suppression might be due to final state interactions. In order to make sure high-p_T suppression is indeed a final state effect, one has to look at situations where final state interactions are supposed to be less important such as dAu collisions. The expectation is that the ratio of dAu to pp-collisions should show an enhancement over a range in momentum, a phenomenon known as the Cronin effect [2]. The argument is that energy loss in the "cold matter" of dAu collisions is quite small and therefore does not mask the Cronin effect which results from p_T

broadening from multiple scattering. On the other hand, if a suppression is observed in dAu colisions at forward rapidities instead of the Cronin effect, it may be an indication that initial state effects are important.

Transverse momentum spectra of hadrons in dAu collisions have shown a lack of high-p_T suppression at mid rapidity. This result is again consistent with the hypothesis of parton energy loss or/and parton recombination in the dense medium formed in AuAu collisions. However, a clear suppression has also been observed in measurements at forward rapidity, suggesting that not only final state effects but also initial state effects may play an important role in high-p_T particle production [1,3].

2. The BRAHMS Experiment

The BRAHMS detector system [4] consists of global detectors for event characterization, a Mid Rapidity Spectrometer(MRS) and a Forward Spectrometer(FS) covering forward rapidities. Collision centrality is characterized by a multiplicity array(MA) consisting of scintillator tiles and silicon strip detectors mounted coaxially around the beam axis. For the present studies, the forward spectrometer was positioned at 4^o with respect to the beam direction, corresponding to $2.9 \leq \eta \leq 3.4$. Events within ± 20 cm of the nominal interaction vertex were considered.

We present here preliminary results on R_{cp} in CuCu Collisions at $\sqrt{s_{NN}} = 200$ GeV measured at the BRAHMS experiment. The CuCu system serves as a bridge between dAu and AuAu systems making it possible to investigate the dependence of high-p_T suppression on system size. Additionally, the data from CuCu collisions allows us to study the dependence of the spectra on the shape of the reaction zone created in the collision. For the same number of participants(N_{part}), the system created in CuCu is more spherical than the one in AuAu.

3. Overview of High-P_T suppression

The total particle production in heavy ion collisions comes from a linear combination of soft processes that scale with the number of participants, and hard processes that scale with the number of binary collisions. Suppression of high-p_T particle production is described in terms of the nuclear modification factor R_{AA}. This is the ratio of the measured hadron spectra to reference spectra from pp collisions scaled by the average number of binary nucleon-nucleon collisions N_{coll}. The value of R_{AA} is expected to be unity if a nucleus-nucleus collision were just a superposition of independent nucleon-nucleon collisions. In the absence of a good pp reference, it is also possible to characterize hadron suppression in terms of R_{cp},the ratio of central to peripheral data scaled by $\langle N_{coll} \rangle$:

$$R_{cp} = \frac{Yield^{central} / < N_{coll}^{central} >}{Yield^{peripheral} / < N_{coll}^{peripheral} >}.$$

The N_{part} (i.e., centrality) dependence offers the possibility of studying the system size dependence of the nuclear modification factor, with the system dependence (CuCu vs. AuAu) supplying additional information on the size dependence. The suppression of high-p_T yields in relativistic heavy ion collisions can have a number of causes. Theoretical models have been developed to describe certain aspects of the experimental data in terms of final state effects such as parton recombination, energy loss, or initial state effects such as CGC. Recent studies based on recombination models [5], for example, seem to give adequate explanation for the different behavior of high-p_T suppression of mesons and baryons. Another mechanism invoked to explain the suppression of high-p_T particle production is a phenomenon known as jet quenching [2,6]. The idea behind jet quenching is that high energy partons traveling through the hot and dense medium created in a heavy ion collision lose energy leading to a high-p_T suppression. A marked high-p_T suppression with increasing rapidity may also be related to the initial conditions, in particular to the possible existence of the color glass condensate(CGC)[7,8]. According to the theory of the CGC, a very high energy hadron has contributions to its wave function from gluons, quarks and anti-quarks. In terms of the momentum fraction x of the partons inside an interacting hadron, low x phenomena correspond to large rapidity. The density of low x gluons grows as energy increases leading to gluon saturation. Parton scattering centers are reduced due to gluon-gluon fusion and, as a result, there should be fewer hard scatterings leading to a reduction in the production of hadrons.

4. R_{cp} results from CuCu

Figure 1(a) shows the ratio R_{cp} of yields from CuCu collisions of a given centrality class to yields from the most peripheral collisions(40-60%), at $\eta = 3.2$, scaled by the number of binary collisions in each sample. The data for the different centrality classes are obtained from the same collider run. As a result, the ratios are largely free of run-dependent systematic errors associated with collider and detector performance. The dominant

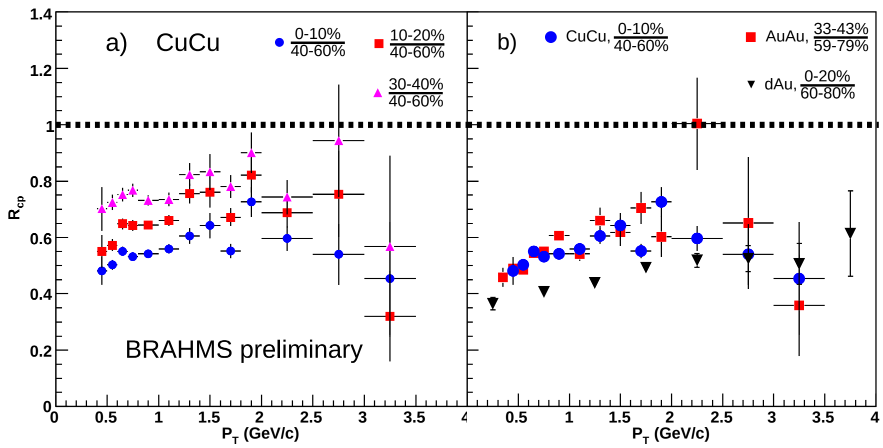

Figure 1. R_{cp} at $\eta = 3.2$ in CuCu Collisions as a function of p_T, (a) Centrality dependence, (b) comparison to results from dAu and AuAu Collisions. For CuCu, $0-10\%$ corresponds to $N_{part} \approx 96.8$ and $40-60\%$ to $N_{part} \approx 18.7$. For AuAu $33-43\%$ corresponds to $N_{part} \approx 96.3$ and $59-79\%$ to $N_{part} \approx 17.8$.

systematic error in the R_{cp} ratios come from the determination of N_{coll} in the centrality bins. One can see that there is more suppression as the collisions become more central.

The R_{cp} in CuCu in comparison with those measured in dAu and AuAu collisions at the same pseudo-rapidity is shown in Figure 1(b). It is evident that the suppression in CuCu follows a similar trend as in dAu and AuAu. Considering the case where the mean number of participants at the same collision energy are equal, one obtains R_{cp} values very similar in both CuCu and AuAu collisions.

5. Summary

In summary, we have presented preliminary results on R_{cp} in CuCu collisions at $\sqrt{s_{NN}} = 200$ GeV and $\eta = 3.2$. Our results show that one obtains similar results for R_{cp} considering the same number of participants in both CuCu and AuAu collisions. This suggests that the observed suppression depends particularly on the volume of the interaction region through which produced hadrons have to travel. To complete the system size systematics, we are currently extending these studies by also studying the correlations with respect to the reaction plane.

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